ZooKeys 4: 71-87 (2008)
doi: 10.3897/zookeys.4.39
www.pensoftonline.net/zookeys

RESEARCH ARTICLE

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

Rare sponges from marine caves: discovery of *Neophrissospongia nana* nov. sp. (Demospongiae, Corallistidae) from Sardinia with an annotated checklist of Mediterranean lithistids

Renata Manconi†, Annalisa Serusi‡

Università di Sassari, Dipartimento di Zoologia e Genetica Evoluzionistica, Italy

† *urn:lsid:zoobank.org:author:ED7D6AA5-D345-4B06-8376-48F858B7D9E3*
‡ *urn:lsid:zoobank.org:author:9EDC3BB4-6C48-4098-BAA5-53619A7A43E8*

Corresponding author: *Renata Manconi* (r.manconi@uniss.it)

Guest editor: *R.W.M. van Soest* | Received 28 September 2008 | Accepted 4 November 2008 | Published 18 December 2008

urn:lsid:zoobank.org:pub:93A5F62F-9A24-4F64-9BFB-C6347AAB45B1

Citation: Manconi R, Serusi A (2008) Rare sponges from marine caves: discovery of *Neophrissospongia nana* nov. sp. (Demospongiae, Corallistidae) from Sardinia with an annotated checklist of Mediterranean lithistids. ZooKeys 4: 71-87. doi: 10.3897/zookeys.4.39

Abstract

A new record of lithistid demosponges is reported from a western Sardinian karstic cave. The new specimen matches the trait of the genus *Neophrissospongia* (Corallistidae) for an ectosomal skeleton of radial dichotriaenes, a choanosomal skeleton as a network of dicranoclone desmas, and streptaster/amphiaster microscleres with short spiny rays bearing blunt tips. The cave-dwelling N. *nana* **nov. sp.** diverges from the other species of the genus in diagnostic characters such as the large irregular plate-like growth form, the topographic distribution of inhalant and exhalant apertures, and a smaller size of all spicular types. Moreover it displays an additional rare second type of dichotriaenes with smooth cladomes, shared with other genera of Corallistidae but never reported before for the genus *Neophrissospongia*. In addition *N. nana* nov. sp. bears style-like sub-ectosomal spicules shared with *N. microstylifer* from deep water of New Caledonia. As for the latter trait, a present in-depth analysis of *N. nolitangere* from the Atlantic Ocean contrasts with previous historical records reporting monaxial spicules as oxeas/anisoxeas. The diagnosis of the genus *Neophrissospongia* is therefore emended for the growth form and for the micro-traits of dichotriaenes and monaxial sub-ectosomal spicules. Morphological data indicate that the new species is allied to *N. nolitangere* and *N. microstylifer* from Eastern Atlantic and New Caledonian deep water, respectively, and its record confirms the highly disjunct geographic range of the genus *Neophrissospongia* in the Lusitanian-Macaronesian-Mediterranean area and the western Pacific Ocean supporting the relic condition of the genus in the Mediterranean Sea. This discovery stresses the key status of Mediterranean palaeoendemics as possible remnants of an ancient Tethyan fauna and focuses the need to plan conservation measures for these rare cave-dwelling sponges.

Copyright *Renata Manconi, Annalisa Serusi.* This is an open access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Keywords
Biodiversity, Mediterranean palaeoendemics, new morpho-traits, cryptic habitat, relic disjunct distribution, conservation

Introduction

Among Demospongiae the archaic polyphyletic group of Lithistid (*sensu* Pisera and Lévi 2002) is present in Europe and North Africa with a highly diversified Jurassic and Cretaceous fossil palaeofauna but apparently very few living representatives have been recorded in the Mediterranean Sea and this recent fauna is poorly-known. Nine species belonging to 9 genera of 6 families have been until now recorded in the Mediterranean Sea (Appendix 1) (Topsent 1892a, 1893, 1925; Vacelet 1960, 1969; Pouliquen 1969, 1972; Pulitzer-Finali 1970, 1972 1983; Pansini 1992, 1995; Boury-Esnault et al. 1994; Magnino et al. 1999; Pansini and Longo, 2003; Perez et al. 2004; Longo et al. 2005; Manconi et al. 2006; Zibrowius and Taviani 2005). The taxonomic richness appears to be notably higher in the tropics (Lévi 1991; Pisera and Lévi 2002; Schlacher-Hoenlinger et al. 2005) whereas the low values in the Mediterranean may be explained by the occurrence of extinction phenomena due to harsh environmental/climatic changes during the history of this basin (e.g. cooling phases in Plio-Pleistocene time, see Wiedenmayr 1994:107). All Mediterranean records refer to genera characterised by a highly disjunct distribution with a spot-like pattern in tropical/subtropical latitudinal ranges of the Atlantic, Indian and western Pacific oceans. These taxonomic and biogeographic patterns suggest the condition of lithistids as remnants of an ancient Tethyan fauna (Reid 1967; Perez et al. 2004; Manconi et al. 2006; Pisera and Vacelet 2006).

We report here the discovery of the genus *Neophrissospongia* Pisera & Lévi, 2002 from a shallow water cave in the western Mediterranean with description of a new species based on a comparative analysis of morphological diagnostic traits *versus* the other species of the genus.

Materials and methods

A large specimen was discovered, photographed *in situ* and collected in part from a shallow water cave of NW-Sardinia by SCUBA diving. The sponge was dissected under a stereomicroscope to observe macro-traits and to obtain representative fragments of the skeleton to be processed by boiling in nitric acid to prepare slides for light microscopy (LM) and stubs for scanning electron microscopy (SEM, ZEISS DSM 962) following standard methods. Growth form, architecture of the ectosomal and choanosomal skeleton, spicular morphology and micrometries, and the topographic localization of spicular types have been considered as diagnostic characters. The number of measured spicules (n) is reported for each spicular type. As for dichotriaenes measurements of

the cladome refer to the total diameter of a virtual circle made by the end points of the clades. Measurements of protoclades and deuteroclades refer to the length of the cladome branches from origin on the shaft to the first dichotomy (protoclade) and from that point to the end of the branch (deuteroclade).

Institutional Acronyms cited in the text:
MSNG Museo civico di Storia Naturale 'G. Doria', Genova, Italy
MNHN Muséum national d'Histoire Naturelle, Paris, France
MOM Musée Océanographique de Monaco, Monaco.

Systematic accounts

Class Demospongiae Sollas, 1885
Family Corallistidae Sollas, 1888

Genus *Neophrissospongia* Pisera & Lévi, 2002

Definition (emended from Pisera and Lévi, 2002)

Cup-shaped, ear-shaped, plate-shaped growth form. Ectosomal skeleton with radially arranged dichotriaenes with tubercled to less frequent smooth cladomes and from smooth to tubercled/spiny rhabdomes. Sub-ectosomal spicules as asterose microscleres (streptaster/amphiaster) and relatively large style-like monaxons. Choanosomal skeleton as a relatively loose network of dicranoclone desmas.

Neophrissospongia nana Manconi & Serusi, nov. sp.

urn:lsid:zoobank.org:act:63EE3CCC-0D80-4A9D-85FD-23B41D21F4EF
(Figs 1-4; Table 1; Appendix 1)

Type locality: Grotta delle Terrazze n. 2740 Catasto Speleologico Regionale (40°34'16"N 08°13'43"E), Punta Giglio Promontory, Alghero, NW Sardinia, 10.iv.2004, R. Barbieri coll. by SCUBA diving.

Type material. Holotype MSNG 54599, fragment of a living specimen. Schizotypes (TER 2) on SEM stubs and slides are deposited at present in the collection of R. Manconi.

Material studied: *Corallistes nolitangere* Schmidt, 1870, p. 23, MNHN DT 781, Fayal, Campagne Prince Albert de Monaco Azores I, leg. E. Topsent, 1 slide; MOM 2144-0-04-0191, large specimen, collection E. Topsent, presumably Azores; AZR 71, collection G. Pulitzer-Finali, 4 slides, unknown locality of Azores.

Description. Known from a single specimen. Growth form as a large thick encrusting plate (10-12 x 5-7 cm) with a wide base adhering to the substrate and rounded margins. The sampled portion (holotype, 5 x 3.5 cm in width, ca. 1.2 cm in thickness) is one third of the entire living specimen. Colour white ice both in vivo

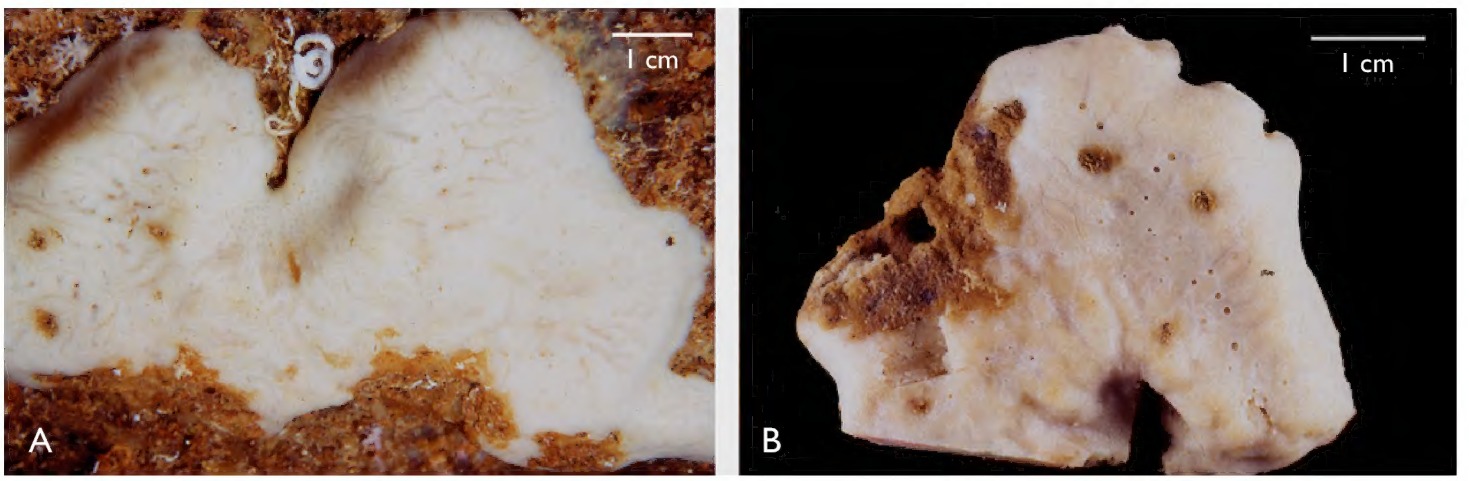

Fig. 1. *Habitus* of the cave-dwelling Mediterranean *Neophrissospongia nana* nov. sp. from north-western Sardinia. A. *In situ* plate-like growth form in the type locality Grotta delle Terrazze (photo by R. Barbieri), B. Holotype MSNG 54599 (top view) (photo by G. Delitala).

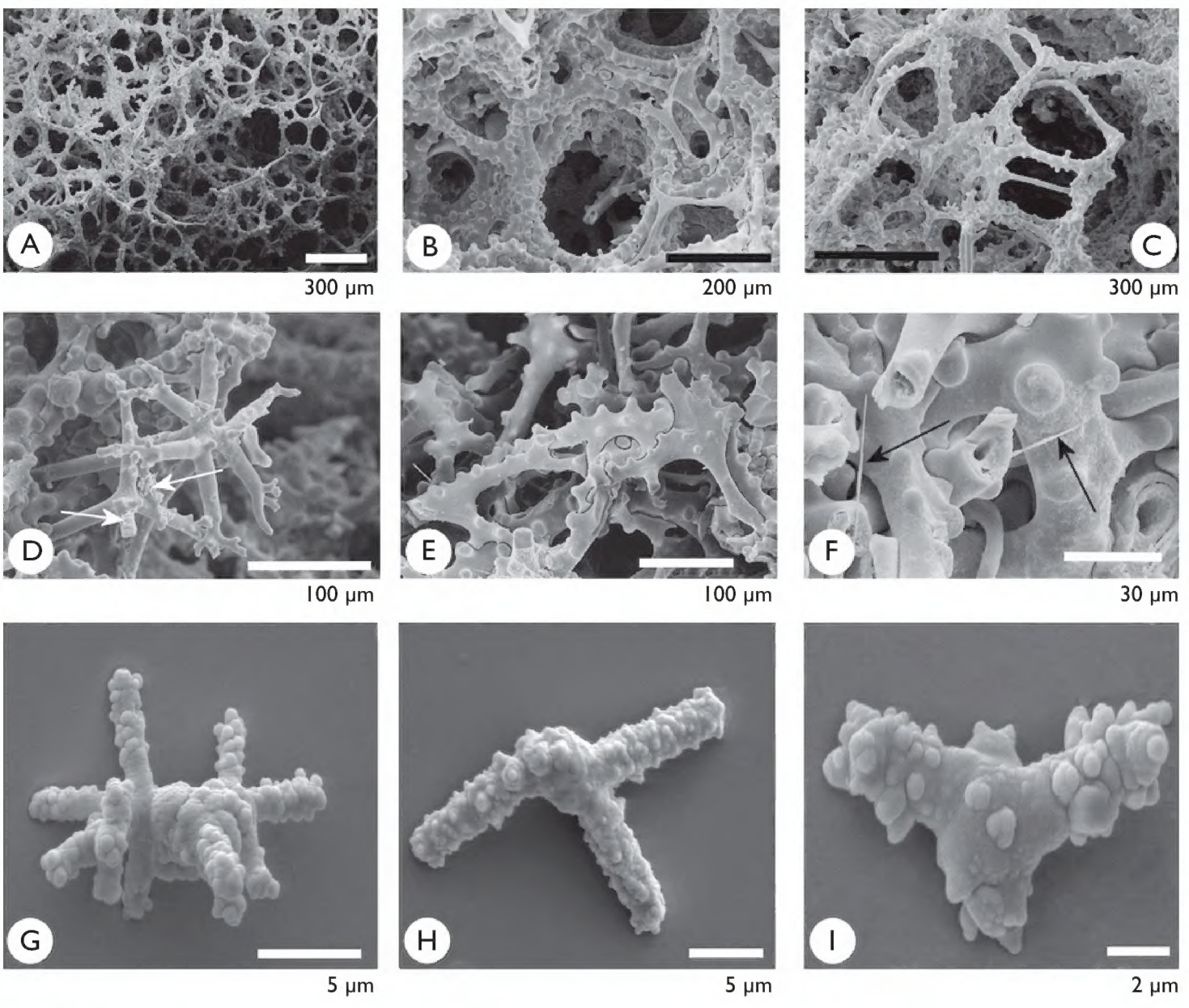

Fig. 2. *Neophrissospongia nana* nov. sp., holotype MSNG 54599, photomicrographs of the skeletal architecture and spicular complement. A-C. Subectosomal skeletal network of dicranoclone desmas. D. Dichotriaene (top) and simple triaene (bottom, arrows) radially arranged in the ectosome with tubercled cladomes. E. Articulation among desmas with scattered styles/sub-tylostyles in the sub-ectosome. F. Detail showing the arrangement of silica in dicranoclone desmas (cross section) and styles/sub-tylostyles (arrows). G-I. Streptaster/amphiaster microscleres with spines/tubercles.

and in spirit, except for a brown degenerated portion at the margin. Consistency stony, harder toward the basal portion. Surface even without asperities, aconulose. Ectosome with irregular sub-dermal canals. Inhalant apertures (0.2-1.2 mm in diameter) grouped in slight concavities along the sponge margins. Exhalant areas scattered on the top surface with grouped oscules (0.5-1 mm in diameter) each with a well-developed vertical atrial canal. Ectosomal skeleton armed by a layer of radially arranged dichotriaenes megascleres of two types. Dichotriaenes with cladomes (145-270 µm in diameter) bearing few tubercles (10-20 µm in height) rarely subdivided at the upper surface of protoclades (20-50 x 10-20 µm, usually 20-30 µm in length) and deuteroclades (50-100 x 10-20 µm, usually 50-70 µm in length). Deuteroclades sometime with branched tips. Rare dichotriaenes with entirely smooth cladomes (93-172 µm in diameter) and scarcely developed clades also present with no differential localization. Rhabdomes with blunt to acute tips (290-540 µm in length) usually smooth, sometimes bearing a few large acute spines or tubercles (up to 30 µm in length) along the axis. Extremely rare triaenes with a few tubercles on the clades also present. Other ectosomal spicules of two types, namely asterose and monaxial. Microscleres as streptaster/amphiaster with short spiny rays (5-15 µm in length) in a variable number (3-7) with blunt tips. Notably thin styles/sub-tylostyles (59-86 µm, < 3 µm in thickness) scattered and tangentially embedded in subectosomal membranes in both the inhalant and exhalant areas.

Architecture of the choanosomal skeleton as a loose network of slender dicranoclone desmas, strongly articulated along the canals of the aquiferous system. Desmas (280-360 µm) with rounded tubercles (5-35 µm in height, usually 10-15 µm) bearing smooth heads. Slender small young desmas with a smooth surface also present.

Diagnosis. *N. nana* nov. sp. is characterised by growth form as a large thick plate with inhalant apertures in concavities along the sponge margins and few conspicuous

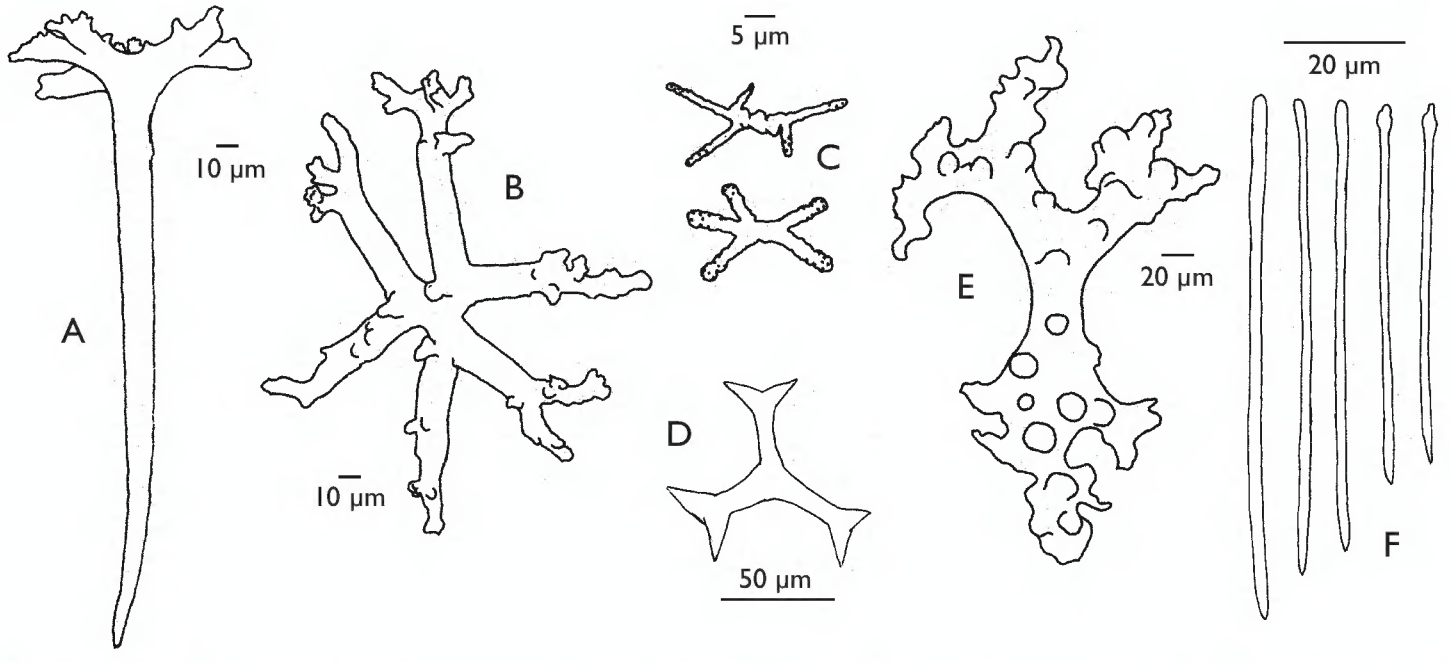

Fig. 3. *Neophrissospongia nana* nov. sp., holotype MSNG 54599, spicular complement. A. Dichotriaene. B. Cladome of a tubercled dichotriaene (top view). C. Streptaster/amphiaster microscleres with tubercles. D. Cladome of a smooth dichotriaene (top view). E. Dicranoclone desma. F. Styles/sub-tylostyles.

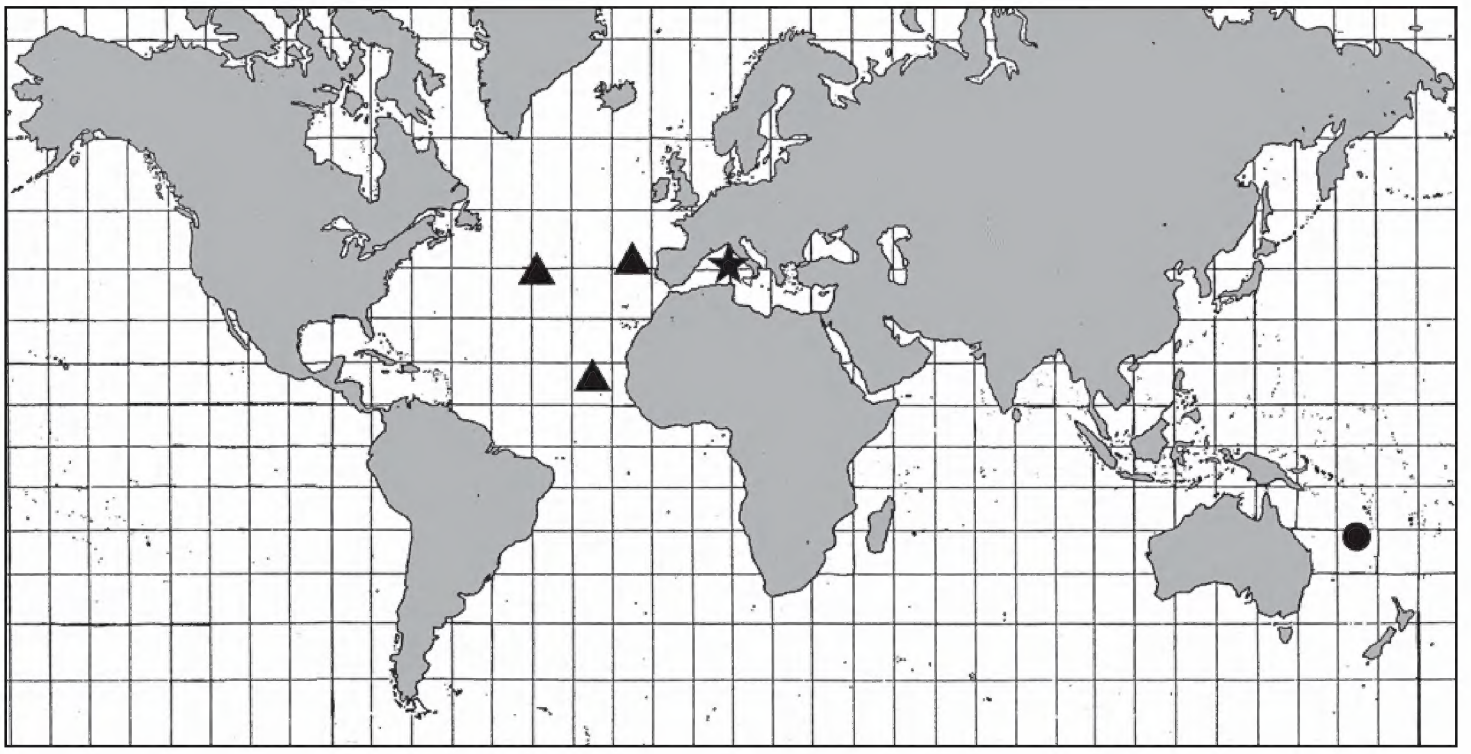

Fig. 4. Geographic range of the genus *Neophrissospongia* with occurrences of the known species *N. nolitangere* in the Atlantic and *N. microstylifer* in the Pacific Ocean. The type locality of *N. nana* nov. sp. from Sardinia is indicated by a star.

exhalant apertures grouped at the top. The spicular complement is characterised by a smaller size of spicules when compared to the other species of the genus. Ectosomal skeleton with tubercled to smooth dichotriaenes (rarely triaenes) radially arranged with no differential topographic distribution. Sub-ectosomal membranes bear styles/subtylostyles tangentially embedded and spiny streptaster/amphiaster microscleres.

Etymology. The specific epithet refers to the small size of the skeletal spicules.

Distribution. Known until now exclusively from the western Sardinian cave Grotta delle Terrazze (type locality).

Habitat. Shallow water (6 m) on the rocky wall in the innermost part of a dark horizontal tunnel (80 m in length) of a submerged cave (160 m along an N-S axis, main entrance at 17 m of depth, 40 m in length, 7 m in width). Another tunnel at the left of the entrance harbours a small population of *Petrobiona massiliana* Vacelet & Lévi (Manconi et al. in press). The absence of sand deposits and the presence of abundant large boulders suggest the cave is subjected to a notably high water movement (south-western winds). In April water temperature was 14 °C. Few serpulids and foraminiferans were found associated with the sponge on an almost bared rocky surface.

Discussion

The genus *Neophrissospongia* was recently erected with *Neophrissospongia nolitangere* (Schmidt, 1870) as type species by Pisera and Lévi (2002) for the species of Corallistidae, characterised by tubercled dichotriaenes, previously ascribed to the genus *Corallistes* Schmidt, 1870. Only two species, *N. nolitangere* (off Portugal,

Tab. I. Distribution, bathymetric range and spicule measurements (length x width) of the species belonging to the genus *Neophrissospongia.*

Species Distribution Depth	Dicrano-clone desma µm	Dichotriaene tubercled/spiny µm	Dicho-triaene smooth µm	Monaxial spicule µm	Streptaster/ Amphiaster µm
N. nolitangere Portugal Schmidt 1870	350-500*	230-310* clad 450-1200*rhabd	not rec	oxea not meas not rec*	10-13x 8-10*
Azores, Fayal Topsent 1892b 1904 365 m	35 thick	45-50 prot 90-100 deut 450-1200 rhabd	not rec	70-100 oxea	10-13
Azores, Fayal MNHN DT 781 present paper	not meas	151-280 clad n=36 35-50x18-20 prot 50-100x18-20 deut 366-1030 x28 rhabd n=15	not meas	style/sub-tylostyle slightly bent/sinu-ous 51-87 x < 3 n=50	not meas
Azores, AZR 71 Pulitzer not publ. present paper depth unknown	not meas	47-58 prot n=20 70-116 deut n=20 478-1200x23-35 rhabd n=16	47-120 prot 47-151 deut	style-like 52-96 x < 3 n=30	9-14 n=15
Sao Tiago Cape Verde Isl. Lendenfeld 1903	35 thick	550 rhabd	not rec	not meas	not rec
N. microstylifer New Caledonia 22°48'S,167°09'E Lévi & Lévi 1983 355-360 m	250-300 clone	250-350 clad 30-40 prot 100 deut 350-600x30-45 rhabd	not rec.	strongyle 25-45x3 subtylostyle 110-170x2	not rec.
N. nana nov. sp. W-Sardinia Terrazze Cave 6 m	280-360 n=30	145-270 clad n=30 20-50x10-20 prot 50-100x10-20 deut 290-540 rhabd n=30	93-172 clad	59-86 x < 3 n=30 subtylostyle	5-15 n=30

* Holotype, Pisera & Lèvi (2002); not meas = not measured; not rec = not recorded; clad = cladome in diameter; prot = protoclade; deut = deuteroclade; rhabd = rhabdome; thick = thickness; n = number of measured spicules.

Azores and Cape Verde Islands) and *N. microstylifer* (New Caledonia) (Schmidt 1870; Carter 1873; Sollas 1888; Lendenfeld 1903; Topsent 1892b, 1904; Desqueiroux and Stone 1992; Lévi and Lévi 1983) have been until now recorded. The most strictly allied taxon of these living forms seems to be the Late Cretaceous fossil genus *Phrissospongia* Moret, 1926 of the family Phrissospongiidae Lagneau-Hérenger, 1962 now junior synonym of Corallistidae (Lévi 1991; Pisera and Lévi 2002; Pisera 2002) characterised by dichotriaenes with deuteroclades vertically oriented (Wiedenmayr 1994: 91).

N. nana nov. sp. matches the diagnostic traits reported for the genus *Neophrissospongia* sharing an ectosomal skeleton of radial dichotriaenes and a choanosomal skeleton as a network of slender dicranoclone desmas. This new species diverges from the other species belonging to the genus in the growth form, smaller spicular size, ornamentations of dichotriaenes (i.e. tubercled cladomes with rarely spined rhabdomes *vs.* entirely smooth) and two types of sub-ectosomal spicules, namely asterose and monaxial. In addition desmas of *N. nana* nov. sp. bear scattered small tubercles with smooth apices as in *N. microstylifer* whereas their surface is microtubercled in *N. nolitangere* (Schmidt 1870; Topsent 1904; Pisera and Lévi 2002).

The ectosomal dichotriaenes of *N. nana* nov. sp. belong to two types, namely with tubercled cladomes to entirely smooth cladomes differing from the typical ones of *N. nolitangere* reported exclusively as tubercled (Schmidt 1870; Topsent 1904; Pisera and Lévi 2002). It may be however that smooth dichotriaenes (Table 1; Figs 2, 3) notably smaller when compared to the tubercled ones, we found also in the Topsent material of *N. nolitangere*, represent young forms.

At the same time, the topographic distribution of streptaster/amphiaster microscleres in the subectosomal skeleton, together with their morphology characterised by short spiny rays bearing blunt tips is shared with *N. microstylifer* and *N. nolitangere*. As for monaxial ectosomal spicules *N. nana* nov. sp. displays styles/sub-tylostyles never recorded before in *N. nolitangere* while they are typical of *N. microstylifer*. Although monaxial spicules has been reported as oxeas/anisoxeas by Carter (1873), Sollas (1888), Lendenfeld (1903) and Topsent (1892, 1904), Pisera and Lévi (2002) did not find this spicular type in the Schmidt's type material of *N. nolitangere*. During the present investigation styles/sub-tylostyles straight to slightly sinuous were also found in the Topsent specimen of *N. nolitangere* we recently rediscovered (MOM) and in the Topsent slide of N. *nolitangere* (MNHN) from Fayal although they have not been found by Pisera and Lévi (2002) probably because they are present exclusively along margins of the slide (MNHN) and are grouped in small fragments of thin membranes like those discovered in *N. nana* nov. sp. in sub-ectosomal membranes. Moreover abundant style-like monaxons have been found also in the material identified by Pulitzer (? *N. nolitangere*, unpubl.) from Azores.

The growth form displayed by *N. nana* nov. sp., as a large thick plate with a peculiar distribution of inhalant areas in concavities, diverges from the shallow cup/ear shape previously recorded for *N. nolitangere*, and the massive or clavate shape typical of *N. microstylifer*. The new species resembles, however the topographic localization of

inhalant and exhalant apertures of the latter species. Spicules of *N. nana* nov. sp. do not match the measurements of the genus and the size range of dichotriaenes, desmas, and streptaster/amphiaster microscleres appears to be notably smaller when compared with *N. nolitangere* reported by Topsent (1892b, 1904) and Pisera and Lévi (2002) together with present measurements. Some spicule measurements match better those of *N. microstylifer* (Lévi and Lévi 1983).

The co-occurrence of two, until now apparently neglected, spicular morphotraits such as style-like and two types of dichotriaenes also in the Topsent and Pulitzer-Finali material of *N. nolitangere* from Azores supports the need of new samplings and a revision of the genus. The *Neophrissopongia* material (as *Corallistes*) in the Schmidt collection (Desqueiroux-Faúndez and Stone 1992) from Strasbourg and Graz is not considered with confidence by Desqueiroux-Faúndez (*in litt.*) and also Pisera and Lévi (2002) are dubious on the type material. At the same time the style-like sub-ectosomal spicules strengthen the phylogenetic relationships between the Atlanto-Mediterranean and Pacific lineages of the genus whereas the smooth morph of dichotriaenes, although rare, may support the relationships among the lineages of the family Corallistidae.

In contrast with the deep bathymetric range of the genus in the Eastern Atlantic and Western Pacific (355-365 m of depth) the discovery of *N. nana* nov. sp. in the innermost dark zone of shallow water cave (6 m of depth) of NW-Sardinia suggests its presence may be relictual. This condition seems to be confirmed by the presence of *Neophrissopongia* spp. also in a few other karstic caves of the Marseille coast and northern Adriatic Sea (Pisera and Vacelet 2006). The presence of *N. nana* nov. sp. in the Mediterranean area fills in part a distributional gap towards the weastern Pacific oceanic region and supports their relic condition suggested by the present day highly disjunct geographic range of the genus *Neophrissopongia* in the Lusitanian-Macaronesian area (*N. nolitangere*) and in the western Pacific Ocean (*N. microstylifer*) (Fig. 4). This geographic pattern confirms the existence of a biogeographic track (*sensu* Croizat 1958) shared with other taxa (e.g. other lithistids). Mediterranean species of the genus *Neophrissopongia* may be representative of a survived stock allied to a highly diverse fossil assemblage mainly dated to Late Jurassic and Late Cretaceous of western-central Europe and North Africa (Reid 1967; Rigby 1983, 1991; Wiedenmayer 1994; Pisera 1999; Finks et al. 2004). Although at present is not possible to clearly discriminate between the hypothetical survival of their ancestors during the harsh climatic/environmental fluctuations of the Mediterranean basin *versus* an immigration process from the Atlantic, this discovery stresses the key status of Mediterranean palaeoendemics as remnants of an ancient Tethyan marine fauna together the need to point out on biodiversity conservation.

The knowledge on the marine palaeoendemic fauna represents a main factor to understand the dynamics and evolution of the Mediterranean basin from the historical biogeography point of view. Investigations focused on this general topic need to be supported by data on taxa characterised by low dispersal power and peculiar geographic patterns. In this field, sponges, in particular, could be useful targets. Sponges

display a life cycle strategy with a meroplanktonic larval stage characterised by a scarce swimming potential that presumably allows only a short planktonic phase with hard constraints on the long distance dispersal.

Key to the species of *Neophrissospongia*

1 Growth form cup- to ear-shaped with small inhalant and large exhalant apertures on opposite sides of the lamella bearing an ectosomal skeleton of dichotriaenes, styles/sub-tylostyles and aster-like microscleres ..... *N. nolitangere*

– Growth form clavate to plate-like with inhalant and exhalant areas in different regions of the same sponge surface 2

2 Growth form clavate, ectosomal skeleton of dichotriaenes and styles/sub-tylostyles ..... *N. microstylifer*

– Growth form plate-like, ectosomal skeleton of dichotriaenes, styles/sub-tylostyles and aster-like microscleres ..... *N. nana* nov. sp.

Acknowledgements

We are grateful to R. Barbieri for the help in sponge collection, and G. Delitala, S. Marceddu (University of Sassari), M. Michetti, Claudio Uliana (University of Genova) for the technical skills. We thank also M. Bruni and M. Magnino (MOM) and I. Coulon and C. Lévi (MNHN) for material loan. Two anonymous reviewers kindly improve the paper. Funds were provided by the European program INTERREG Sardinia-Corsica-Tuscany on Biodiversity, the Italian Ministero dell'Università e della Ricerca Scientifica e Tecnologica (MIUR-PRIN 2004057217 'Zoogeography of Mediterranean-southern African disjunct distributions by a multimethod approach'), the Università di Sassari and the Fondazione Banco di Sardegna. The Italian Ministero dell'Ambiente ("Studio degli ambienti di grotte marine sommerse ("Codice Habitat 8330) nelle Aree Marine Protette di Pelagie, Plemmirio e Capo Caccia") supported in part this research.

References

Boury-Esnault N, Pansini M, Uriz MJ (1994) Spongiaires bathyaux de la mer d'Alboran e du golfe ibéro-marocaine. Mémoires du Muséum national d'histoire naturelle 160: 1-174

Carter HJ (1873) On the Hexactinellidae and Lithistidae generally, and particularly on the Aphrocallistidae, *Aulodyction,* and *Farreae*, together with facts elicited from their deciduous structures and descriptions respectively of three new species. Annals and Magazine of Natural History (4) 12(71): 349-373, 437-472.

Croizat L (1958) Panbiogeography. Vols 1, 2. Caracas, Venezuela, Published by the author.

Desqueiroux-Faúndez R, Stone SM (1992) O. Schmidt sponge catalogue. An illustrated guide to the Graz Museum Collection, with notes on additional material. Muséum d'Histoire naturelle, Geneva: 1-190.

Finks RM, Reid REH, Rigby JK (2004) Porifera. In: Kaesler RL (Ed) Treatise on Invertebrate Paleontology Part E. The Geological Society of America & The University of Kansas, Boulder, Colorado, and Lawrence, Kansas, 3: 1-872.

Lendenfeld R von (1903) Porifera. Tetraxonia. In: Schulze FE (Ed) Das Tierreich 19 Friedländer Berlin, 1-168.

Lévi C, Lévi P (1983) Éponges Tetractinellides et Lithistides bathyales de Nouvelle-Calédonie. Bulletin du Muséum National d'Histoire naturelle Paris, IV Sér., 5A: 101-168.

Lévi C (1991) Lithistid sponges from the Norfolk Rise. Recent and Mesozoic genera. In: Reitner J, Keupp H (Eds) Fossil and Recent Sponges. Springer-Verlag, Berlin, 72-82.

Longo C, Mastrototaro F, Corriero G (2005) Sponge fauna associated with a Mediterranean deep-sea coral bank. Journal of the Marine Biological Association of the United Kingdom 85: 1341-1352.

Magnino G, Gravina MF, Righini P, Serena F, Pansini M (1999) Due demosponge Lithistidi nuove per i mari italiani. Biologia Marina Mediterranea 6: 391-393.

Manconi R, Serusi A, Pisera A (2006) A new Mediterranean 'Lithistid' sponge, *Aciculites mediterranea* sp. n. (Porifera, Demospongiae) from a dark marine cave in Sardinia. Journal of the Marine Biological Association 86: 691-698.

Manconi R, Ledda FD, Serusi A, Corso G, Stocchino GA (in press) Sponges of marine caves: Notes on the status of the Mediterranean palaeoendemic *Petrobiona massiliana* (Calcarea: Lithonida) with new records from Sardinia. Italian Journal of Zoology.

Muricy G, Minervino JV (2000) A new species of *Gastrophanella* from central western Atlantic, with a discussion of the family Siphonidiidae (Demospongiae: Lithistida). Journal of the Marine Biological Association of the United Kingdom 80: 599-605.

Pansini M (1992) Considérations biogéographiques et systématiques pour une mise à jour des données sur le peuplement de spongiaires méditerranéens. Bulletin de l'Institut Océanographique 9: 43-51.

Pansini M (1995) Porifera. In: Minelli A, Ruffo S, La Posta S (Eds) Checklist delle specie della fauna italiana. Bologna, Calderini, 1-23.

Pansini M, Longo C (2003) A review of the Mediterranean Sea sponge biogeography with, in appendix, a list of the demosponges hitherto recorded from this sea. Biogeographia 24: 59-90.

Pansini M, Pronzato R (1973) Il coralligeno di Bogliasco ed il suo popolamento di Poriferi. Bollettino dei Musei e degli Istituti Biologici dell'Università di Genova 41: 5-34.

Perez T, Vacelet J, Bitar G, Zibrowius H (2004) Two new lithistids (Porifera: Demospongiae) from a shallow eastern Mediterranean cave (Lebanon). Journal of the Marine Biological Association of the United Kingdom 84: 15-24.

Pisera A (1999) PostPaleozoic history of the siliceous sponges with rigid skeleton. Memoirs of the Queensland Museum 44: 463-472.

Pisera A (2002) Fossil 'Lithistid': an overview. In: Hooper JH, van Soest RVM (Eds) Systema Porifera. A guide to the classification of sponges, Vol. 1. New York: Kluwer Academic/ Plenum Publisher, 388-402.

Pisera A, Lévi C (2002) 'Lithistid' Demospongiae. In: Hooper JH, van Soest RVM (Eds) Systema Porifera. A guide to the classification of sponges, Vol. 1, New York, Kluwer Academic/ Plenum Publisher, 299-383.

Pisera A, Vacelet J (2006) Lithistid sponges from submarine caves in the Mediterranean: Taxonomy and affinities. In Custódio MR, Lôbo-Hajdu G, Hajdu E, Muricy G (Eds) 7th International sponge Symposium Biodiversity, Innovation, Sustainability, Armação de Buzios, Brazil, 7-13 May 2006. Museu Nacional Rio de Janeiro, 232.

Pouliquen L (1969) Remarques sur la présence d'éponges de l'étage bathyal dans les grottes sous-marines obscures en Méditerranée. Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences 268: 1324-1326.

Pouliquen L (1972) Les Spongiaires des grottes sous-marines de la région de Marseille. Ecologie et systématique. Tethys 3(4): 715-758.

Pulitzer-Finali G (1972) Report on a collection of sponges from the Bay of Naples. I. Scleraspongiae, Lithistida, Tetractinellida, Epipolasida. Pubblicazioni della Stazione Zoologica di Napoli 38: 328-354.

Pulitzer-Finali G (1983) A collection of Mediterranean Demospongiae (Porifera) with, in appendix, a list of the Demospongiae hitherto recorded from the Mediterranean Sea. Annali del Museo Civico di Storia Naturale "Giacomo Doria" 84: 445-621.

Reid REH (1967) Tethys and the zoogeography of some modern and Mesozoic Porifera. In: Adams CG, Ager DV (Eds) Aspects of Tethyan biogeography. Systematic Association Publication 7: 171-181.

Rigby JK (1983) Fossil Demospongiae. In: Rigby JK, Stearn CW (Eds) Sponges and spongiomorphs. Notes for a Short Course. Studies in Geology 7: 12-39.

Rigby JK (1991) Evolution of Paleozoic heteractinid calcareous sponges and demosponges. Patterns and records. In: Reitner J, Keupp H (Eds), Fossil and recent sponges. Berlin, SpringerVerlag, 83-101.

Schmidt O (1870) Grundzüge einer Spongien-Fauna des atlantischen Gebietes. Wilhelm Engelmann, Leipzig, 88 pp.

Schlacher-Hoenlinger MA, Pisera A, Hooper JNA (2005) Deep-sea 'Lithistid' assemblages from the Norfolk Ridge (New Caledonia), with descriptions of seven new species and a new genus (Porifera: Demospongiae). Zoosystema 27: 649-698.

Soest R van, Hajdu E (2000) New species of *Desmanthus* (Porifera, Demospongiae) with a discussion on its ordinal relationships. Zoosystema 22(2): 299-312.

Sollas WJ (1888) Report on the Tetractinellida collected by H.M.S. 'Challenger' during the years 1873-1876. Report on the Scientific Results of the Voyage of H.M.S. 'Challenger', 1873-1876. Zoology 25(63): 1-458.

Topsent E (1892a) Diagnoses d'éponges nouvelles de la Méditerranée et plus particulièrement de Banyuls. Archives de Zoologie Expérimentale et Générale 10(6): 17-28.

Topsent E (1892b) Contribution à l'étude des Spongiaires de l'Atlantique Nord (Golfe de Gascogne, Terre-Neuve, Açores). Résultats des campagnes scientifiques accomplies par le Prince Albert I. Monaco 2: 1-165.

Topsent E (1893) Nouvelle serie de diagnoses d'éponges de Roscoff et de Banyuls. Archives de Zoologie Expérimentale et Générale 3: 33-43.

Topsent E (1898) Eponges nouvelles des Açores. Mémoires de la Société zoologique de France 11: 225-255.

Topsent E (1904) Spongiaires des Açores. Résultats des campagnes scientifiques accomplies par le Prince Albert I. Monaco 25: 1-280.

Topsent E (1925) Etude des spongiaires du Golfe de Naples. Archives de Zoologie Expérimentale et Générale 63(5): 623-725.

Vacelet J (1960) Eponges de la Méditerranée nord-occidentale récoltées par le 'Président Théodore Tissier' (1958). Revue des Travaux de l'Institut des Pêches Maritimes 24: 257-272.

Vacelet J (1969) Eponges de la roche du large et de l'étage bathyal de Méditerranée (Récoltes de la soucoupe plongeante Cousteau et dragages). Mémoires du Muséum National d'Histoire Naturelle (A, Zoologie) 59: 145-219.

Vamvakas CN (1971) Contribution in the study of soft substrata benthic communities in the Hellenic Seas, West Saronikos Gulf area. Hellenic Oceanology and Limnology 20: 129-272.

Vosmer GCJ (1935) The sponges of the Bay of Naples, Porifera Incalcaria. Vol II. Capita Zoologica 5: 457-828, 829-848.

Wiedenmayer F (1994) Contribution to the knowledge of post-Palaeozoic neritic and archibental sponges (Porifera).The stratigraphic record, ecology, and global distribution of intermediate and higher taxa. Schweizerische Palaontologische Abhandlungen 116: 1-147.

Zibrowius H, Taviani M (2005) Remarkable sessile fauna associated with deep coral and other calcareous substrates in the Strait of Sicily, Mediterranean Sea. Cold-water corals and ecosystems. Erlangen Earth Conference Series. Springer, Berlin, 807-819 pp.

Appendix I. Annotated checklist of lithistid sponges in the Mediterranean Sea.

Family Scleritodermidae Sollas, 1888

Genus *Aciculites* Schmidt, 1879

Distribution: Barbados, Cuba, Mediterranean, Madagascar, Kenya, Sri Lanka, New Caledonia, New Zealand, Philippines (Pisera and Lévi 2002; Manconi et al. 2006).

Aciculites mediterranea Manconi, Serusi & Pisera, 2006

Sardinia Sea, Grotta dei Laghi, 40°34'N81°4'E, dark cave, 7.5 m of depth, VIII.2000, R. Barbieri leg., SCUBA diving, formalin/alcohol (Manconi et al. 2006)

Distribution. Only known from the type locality aW-Mediterranean cave.

Genus *Microscleroderma* Kirkpatrick, 1903

Distribution: Off KwaZulu-Natal, south Arabia, Sri Lanka, Philippines, New Caledonia, Caribbean, Mediterranean (Pisera and Lévi 2002; Perez et al. 2004).

Microscleroderma lamina Perez, Vacelet, Bitar & Zibrowius, 2004

MNHN D JV 76-77-78, Levant basin, N-Lebanon, Chak El Hatab, lithistid dark cave, 34°17'63N 35°40'27E, 2 m of depth, 21.ix.2002, G. Bitar and H. Zibrowius leg., SCUBA diving, dry/formalin/alcohol (Perez et al. 2004)

Distribution: Only known from the type locality an E-Mediterranean cave.

Family Corallistidae Sollas, 1888

Genus *Corallistes* Schmidt, 1870

Distribution: Florida, Caribbean, Mexican Gulf, Brazil, southern africa (KwaZulu-Natal coast), New Caledonia, Papua New Guinea (Pisera and Lévi 2002).

Corallistes masoni (Bowerbank, 1869)

Lion Gulf, Marseille coast, Figuier dark cave, 43°20'N 5°25'E, 12 m of depth, SCUBA diving (Pouliquen 1972)

Lion Gulf, Marseille coast, Morgiou, dark cave, 30 m of depth, SCUBA diving (Pouliquen 1972)

NE-Ligurian Sea, S. Lucia Bank, 43°34'N 09°28'E, seamount, muddy bottom, 550-640 m of depth, trawling (Magnino et al. 1999);

Central Tyrrhenian Sea, white corals bank, 400-600 m of depth, trawling (Magnino et al. 1999)

Distribution: W-Mediterranean, Cape Verde Islands, Madeira.

Genus *Neophrissospongia* Pisera & Lévi, 2002

Distribution. Eastern Atlantic Ocean, Mediterranean Sea and western Pacific Ocean (Pisera and Lévi 2002; present paper).

Neophrissospongia nana Manconi & Serusi, nov. sp.

Sardinia Sea, NW Sardinia, Punta Giglio Promontory, Grotta delle Terrazze n. 2740 Catasto Speleologico Regionale, 40°34'16"N 08°13'43"E, R. Barbieri leg., 10.IV.2004, SCUBA diving, (present paper).

Distribution: Only known from the type locality, a cave in W-Mediterranean.

Family Theonellidae Lendenfeld, 1903

Genus *Discodermia* Du Bocage, 1870

Distribution: Atlantic Ocean, Mediterranean Sea (Pisera and Lévi 2002).

Discodermia polydiscus (Bowerbank, 1869)

Lion Gulf, Marseille coast, Figuier dark cave, 43°20'N 5°25'E, 12 m of depth, SCUBA diving (Pouliquen 1972)

Lion Gulf, Marseille coast, Trémies dark cave, 43°20'N 5°30'E, shallow water, SCUBA diving (Pouliquen 1972)

Lion Gulf, Marseille coast, Castelviel dark cave, SCUBA diving (Pouliquen 1972)

Lion Gulf, Marseille coast, Morgiou dark cave, 43°12'N 5°26'E, 30 m of depth, SCUBA diving (Pouliquen 1972)

Aegean Sea, 36°26'N 25°21'E, muddy bottom and white corals bank, 210 m of depth, by dredge, 20.V.1964 (Vacelet 1969)

Aegean Sea, Canal of Cerigotto,between Crete and Peloponneso, 35°45'N 23°25'E, 360 m of depth, by dredge, muddy bottom and white coral bank, alcohol (Vacelet 1969)

Aegean Sea, Athene Bay, 37°58'N 23°43'E, 60 m of depth (in Pouliquen 1972 p. 751)

Distribution: Caribbean, Atlantic Ocean and Mediterranean Sea, Caribbean, Atlantic Ocean.

Family Siphonidiidae Lendenfeld, 1903

Genus *Siphonidium* Schmidt, 1879

Distribution: Florida, Caribbean, Azores, Western Africa, Mediterranean, Indonesia, New Caledonia (Pisera and Lévi 2002).

Siphonidium ramosum (Schmidt, 1870)

Lion Gulf, Canyon of Cassidaigne, Marseille, 43°13'N 5°4'E, on fossil oysters, deep water, by dredge, 20.IX.1966, alcohol (Vacelet 1969)

Northern Tyrrhenian Sea, E-Corsica, epibathyal muddy bottoms, 565-610 m of depth trawling (Vacelet 1960, 1969);
Central Tyrrhenian Sea, Bay of Naples, Posillipo, 40°49'N 14°13'E, 20 m of depth, associated with *Phakellia robusta* (Vosmer 1935; Topsent 1925; Vacelet 1969);
Ionian Sea, Apulia, off Cape S. Maria di Leuca, st. 4-6-8-9, 39°31'/39°37'N 18°23'/18°39'E, 14-16.II.2001, 640-681 m of depth, by "ingegno", formalin (Longo et al. 2005)
Strait of Sicily, Cruise CS96, RV Uran, on deep corals, 250-1000 m of depth (Zibrowius and Taviani 2005)
Distribution: Atlantic Ocean, Mediterranean Sea, Indonesia.

Genus *Gastrophanella* Schmidt, 1879

Distribution: West Indies, Belize, Pacific coast of Mexico, Brazil, Mediterranean, South Africa (Muricy and Minervino 2000; Pisera and Lévi 2002; Perez et al. 2004).

Gastrophanella phoeniciensis Perez, Vacelet, Bitar & Zibrowius, 2004

MNHN D JV 73-74-75, Levant basin, N-Lebanon, Chak El Hatab, Lithistid cave, 34°17'63N 35°40'27E, 21.IX.2002, G. Bitar and H. Zibrowius leg., 2 m of depth, SCUBA diving, formalin/alcohol (Perez et al. 2004)
Distribution: Only known from the type locality an E-Mediterranean cave.

Family Azoricidae Sollas, 1888

Genus *Leiodermatium* Schmidt, 1870

Distribution: Atlantic, Mediterranean Sea, Pacific Ocean, (Pisera and Lévi 2002).

Leiodermatium lynceus Schmidt, 1870

Central Tyrrhenian Sea, muddy bottom and white coral bank, 700 m of depth, trawling (Magnino et al. 1999)
Aegean Sea (Vamvakas 1971)
Ionian Sea, Apulia, off Cape S. Maria di Leuca, st. 15, 39°36'/39°37'N 18°23'E, 16.II.2001, 430-469 m of depth, by "ingegno", formalin (Longo et al. 2005)
Distribution: Mediterranean Sea, Atlantic and Pacific Ocean.

Family Desmanthidae Topsent, 1893

Genus *Desmanthus* Topsent, 1894

Distribution: Caribbean, southern Atlantic, Mediterranean, Madagascar, Indian Ocean, Pacific coast of Panama, Philippines, Papua New Guinea (Pisera and Lévi 2002).

Desmanthus incrustans (Topsent 1889)

Lion Gulf, Banyuls, 42°28'N 3°7'E (Topsent 1893);
Lion Gulf, Cap l'Abeille, 42°28'N 3°8'60"E, 30-40 m of depth (in Pouliquen 1972 p. 751)
Lion Gulf, Marseille coast, Trémies dark cave, 43°20'N 5°30'E, SCUBA diving (Pouliquen 1969, 1972)
Ligurian Sea, Portofino, Aurora, 44°18'N 9°12'E, 13 m of depthrocky bottom, XI.1976, SCUBA diving (Pulitzer-Finali 1983)
Ligurian Sea, Bogliasco, 44°22'N 9°4'E, 10-15 m, coralligenous on vertical cliffs, SCUBA diving (Pansini and Pronzato 1973)
Central Tyrrhenian Sea, Ischia, Monte Vico, 40°43'N 13°54'E, semi-dark cave, 3-4 m of depth, SCUBA diving, 7.VIII.1968 (Pulitzer-Finali 1972)
Ionian Sea, Leuca, 39°47'N 18°20'E, 2-3 m of depth, shallow water cave, SCUBA diving, 9.VII.1967 (Pulitzer-Finali 1983)
Distribution: Western and Central Mediterranean Sea, Caribbean, Indian Ocean, Philippines, Papua New Guinea (van Soest and Hajdu, 2000; Pisera and Lévi 2002).

Genus *Sulcastrella* Schmidt, 1879

Distribution: Florida, Barbados and Western Mediterranean Sea (Pisera and Lévi 2002).

Sulcastrella tenens (Vacelet, 1969)

Lion Gulf, eastern Canyon of Cassidaigne, 43°13'N 5°4'E, 235 m of depth, by dredge, encrusting on rock, dry (Vacelet 1969)
Corsica Sea, W-Corsica, 210-240 m of depth, 1965, by dredge, on madreporarians, alcohol (Vacelet 1969)
Distribution: Only known from the Western Mediterranean Sea.